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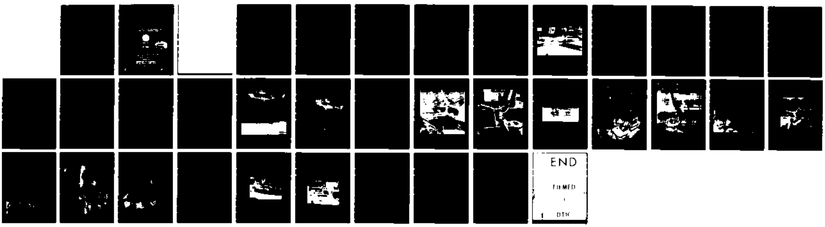

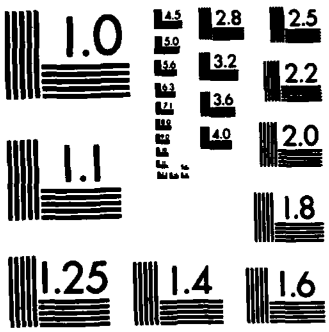

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16. Abstract

An operational test and evaluation was conducted on a lightweight, modularized 2000 gpm, self-contained, gas turbine driven fire fighting pump.

The NASA/U.S. Coast Guard jointly developed firefighting module is intended to remain in long term unattended, unprotected storage ready for immediate deployment to a fire scene over the road by trailer, by helicopter or on board Coast Guard vessels. It could be used for fighting fires in and around the waterfront, on ships at sea or in port and on offshore structures.

Following performance, endurance and shock tests, it was operated on board a 32 foot ports and waterways boat, and an 82 foot patrol boat. Air Transportability was evaluated with an HH-3 helicopter. It was concluded that the module in its present configuration is not suitable for Coast Guard servicewide use.

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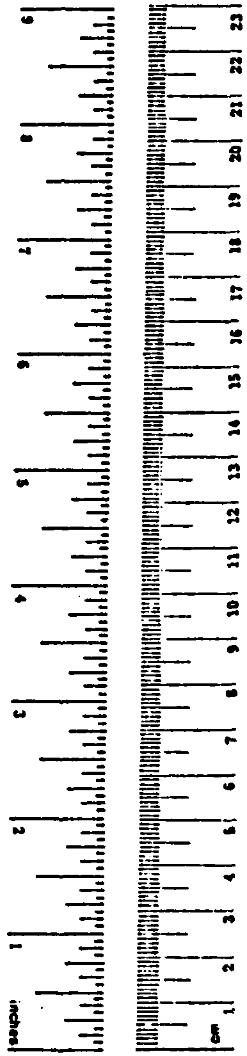
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

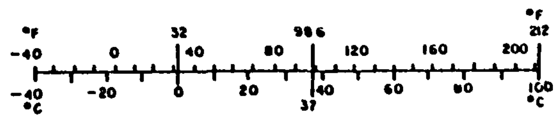
Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



APPRECIATION

The Research and Development Center expresses its appreciation to the following Coast Guard commands and units which assisted with and participated in the test and evaluation of the Fire Fighting Module:

Commander Eighth Coast Guard District
Commander, U.S. Coast Guard Group Mobile, AL
U.S. Coast Guard Base, Mobile, AL
U.S. Coast Guard Marine Safety Office, Mobile, AL
U.S. Coast Guard Air Station, New Orleans, LA
U.S. Coast Guard Cutter, Point Verde (CG-82311)

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1.0 INTRODUCTION

This report describes the field test and evaluation of a prototype Lightweight Fire Fighting Module, designed and built by Northern Research Engineering Corp. (NREC) of Cambridge, MA under contract NAS8-31977 funded jointly by NASA and the Coast Guard. The prototype module was to be self contained and designed to deliver 2000 GPM at a nozzle pressure of 150 PSIG with a suction lift of 20 feet. The design specifications called for an envelope dimension of 6 feet in length by 5 feet in width, and 4 feet in height. The overall weight was to be less than 2,300 pounds, including fuel for three hours of operation.

The module is intended to remain in long-term unattended and unprotected storage ready for immediate deployment to a fire scene over the road by trailer, onboard Coast Guard vessels and by helicopter. It could be used for fighting fires in and around the waterfront, ships at sea or in port, and on offshore platforms. Figure 1.

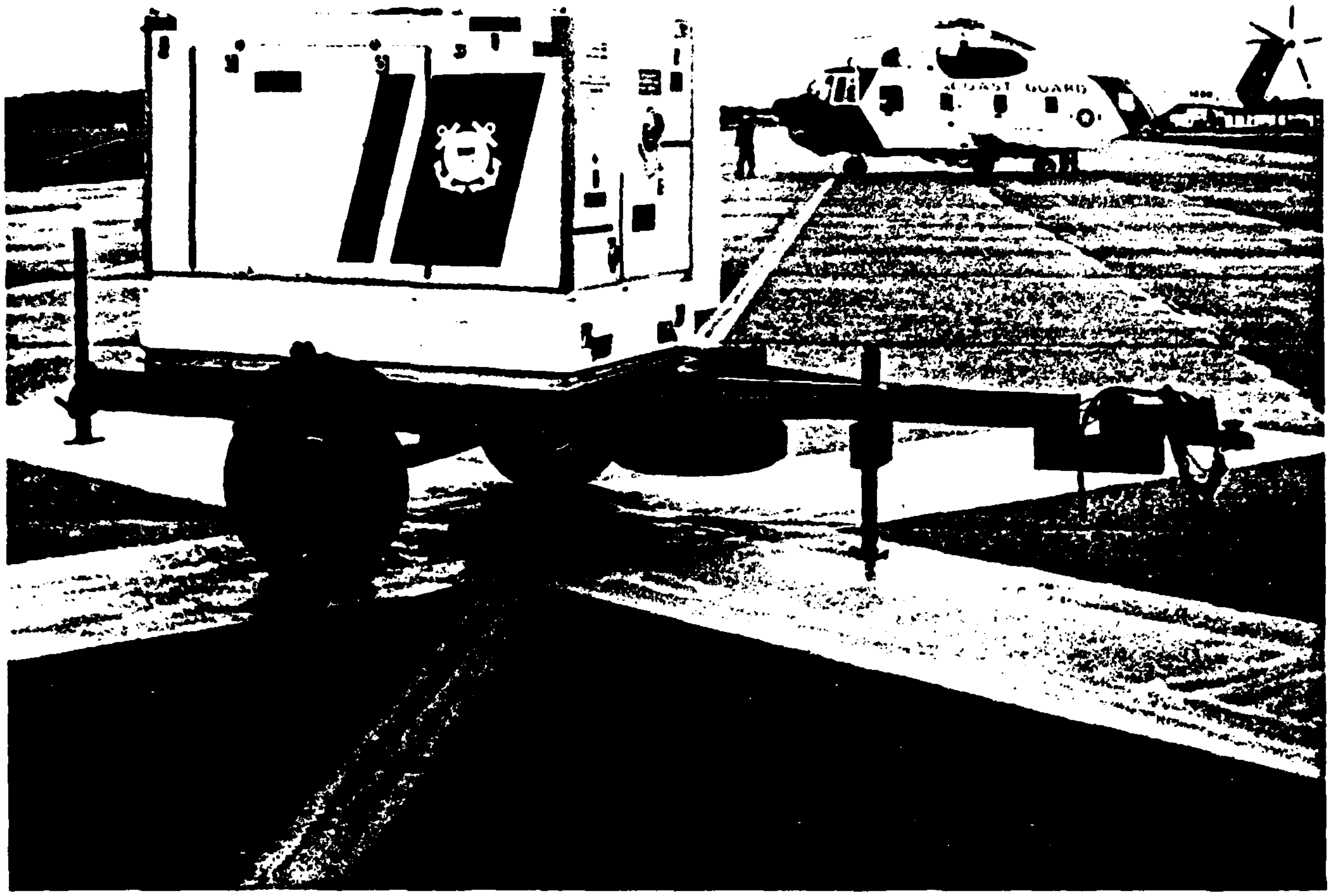

FIGURE 1. 2,000 GPM LIGHTWEIGHT FIRE FIGHTING MODULE AND TRAILER

2.0 SUMMARY

The fire fighting module was delivered in February 1979 to the Coast Guard Research and Development Center's Fire and Safety Test Detachment, Mobile, Alabama for field tests and evaluation. Tests consisted of:

- a 100 hour endurance test
- a shock test by dropping from a height of twelve inches to a concrete base
- a fuel endurance test
- installation and operation onboard a 32 foot Ports and Waterways Boat (PWB)
- simulated fighting a deck fire onboard a cargo ship from 32' PWB
- installation onboard an 82 foot Patrol Boat (WPB).
- transportation by HH-3 helicopter

As built, the fire fighting module was not considered suitable for long-term unattended storage in the weather because of: numerous ferrous fasteners and components; pockets in which rain water can accumulate and the non-weathertight enclosure.

The module can be installed on and operated successfuly from a 32' PWB. However, when so installed it covers the boat's engine hatches preventing access to the engine compartment as long as it is onboard.

The module can be lifted and transported by an HH-3 helicopter. However, because of its weight a 30 minute flight would be the maximum range and modifications needed to be made to improve its aerodynamic qualities.

The pump required complete overhaul following 100 hours of operation. It is not recommended for servicewide use in its present configuration.

3.0 DESCRIPTION

The prototype lightweight fire fighting module consists of a gas turbine powered two stage pump, engine controls, and monitoring instrumentation for fully automatic operation, and provisions for storing all associated fire fighting equipment and fuel within the module housing, as follows:

Module	Fiberglass reinforced plastic housing with stainless steel lifting straps down each corner. Overall dimensions are 72" long x 60" wide x 48" high.
Fuel Tank	100 gallons diesel oil in base of module.
Engine	349 HP gas turbine Allison Model 250-C20
Pump	Two stage aluminum housing with aluminum impellers and inducer 2000 GPM rated discharge at 150 psig
Suction Hose	10" dia. fiberglass reinforced plastic
Discharge Hose	4" dia. fire hose 25' in length
Monitors	Two 3.5" in diameter with 1 1/2" and 2" nozzles
Trailer	Two wheel flat bed rated up to 50 mph highway speed

4.0 TESTS AND EVALUATIONS

The testing and evaluations were conducted between February and July 1979. The first test to be conducted was a one hundred hour endurance test followed by fuel consumption, a shock test and deployment onboard a 32 foot Ports and Waterways Boat (PWB) and an 82 foot Patrol Boat (WPB). Upon completion of the evaluations, the pump was disassembled for inspection and repair.

4.1 100 Hour Endurance Test

At the beginning of the test schedule, a one hundred hour endurance test was conducted. This involved running the pump at various speeds with different nozzles, various suction heights to determine suction lifts, and performance of the machinery and associated equipment. Twenty-six days had elapsed from the time the pump had been accepted at the builder plant in Boston, MA and tests were to begin at Mobile, AL. In that per , the main impellers in the pump had seized from corrosion and could not rotated from pump end. The engine spline back plate had to be removed from engine in order to free the pump shaft by rotating it with a special jack tool.

Approximately 1/2 to 3/4 inch of water had collected ue the module enclosure. Rust and corrosion had started accumulating on steel tubings, engine and pump casings, batteries, and wires. Three holes were drilled through the side cover for draining liquids from inside the enclosure.

Since during the first week of operation, fuel problems plagued the engine, a thorough inspection of the fuel system was conducted. Fuel lines were tightened, strainers were cleaned and primed. It was concluded that the check valve between the fuel shut off valve and the tank was allowing fuel to drain back to the tank. Toward the end of the second week, the operators were experiencing problems with the electronic fuel control panel systems, the battery charger wouldn't operate properly, indicator lights were operating improperly, RPM Gauge was eratic, the voltage regulator was not charging the batteries and the starter was not energizing. These problems were traced to the high voltage relay and transformer box. The box was found to be not properly sealed where wiring penetrated its inboard side. This caused the electrical wires and connections to corrode, and deteriorate to a point that the entire box had to be replaced.

The voltage regulator malfunctioned due to problems with the high voltage relay box. The starting batteries had to be charged with a portable battery charger. Low voltage caused extensive heat in the fuel oil solenoid coil. The coil burned out, cutting off fuel to the engine. It was difficult to locate a replacement 24 volt D.C. solenoid coil.

After the unit had operated a total of 88 hours, an inspection of the seals, bearings, inducer housing and impeller was conducted to determine the condition of the pump prior to the operational evaluation stage. Results indicated that all the parts had very little or no wear, so the pump was reassembled and returned to operational status.

4.2 Fuel Oil Consumption

The built in fuel oil tank on the unit was filled to capacity, and the pump was operated under load at various speeds to determine how long the pump could operate on a full tank of fuel oil. The results of these tests are plotted in Figure 2.

4.3 Shock Test

The shock tests consisted of lifting the entire module and equipment twelve inches off the ground and than releasing it. The objective of this test was to simulate shocks which might be experienced by the module during air transport and when loading on board vessels. No noticeable damage was sustained in this test.

4.4 Starting and Stopping

The unit was started and stopped seven times in quick succession to determine whether or not there was any problem in the starting system. The pump was put into operation for thrity minutes and secured for thirty minutes. The gas turbine engine requires a cool down period of approximately thirty minutes before a restart. No problems were experienced during this phase of the testing.

4.5 Sound Level Evaluation

Sound level measurements were taken at various points around the module to determine the level of sound to which operating personnel would be exposed. The normal levels were obtained with a Bruel and Kjaer sound level instrument. The results are plotted in Figure 3.

4.6 Pump Performance

Pump flow rates were obtained by installing a Dieterick "Eagle Eye" meter in each discharge line at their monitors. The pump was operated at various speeds to measure the flow rate. The suction lifts during this test varied as the tide changed. Results are shown in Figure 4.

4.7 Helicopter Operations

Four days of helicopter operations were scheduled. The first day entailed, preparing the module for flight. All access doors to the envelope had to be bolted or taped closed, the six sections of suction pipe had to be removed, shackles on lifting cables had to be changed to a larger size, a

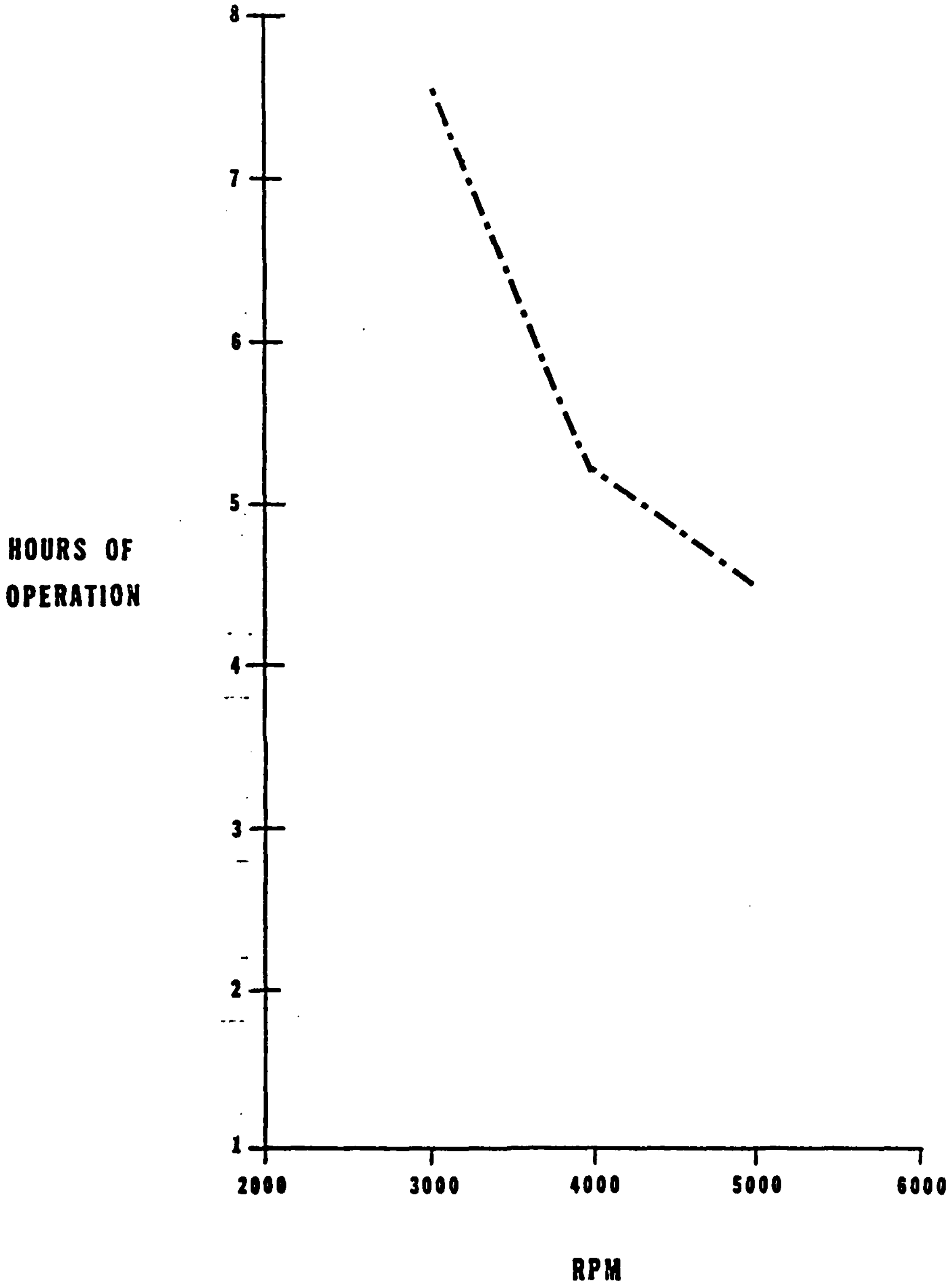

FIGURE 2. FUEL OIL CONSUMPTION

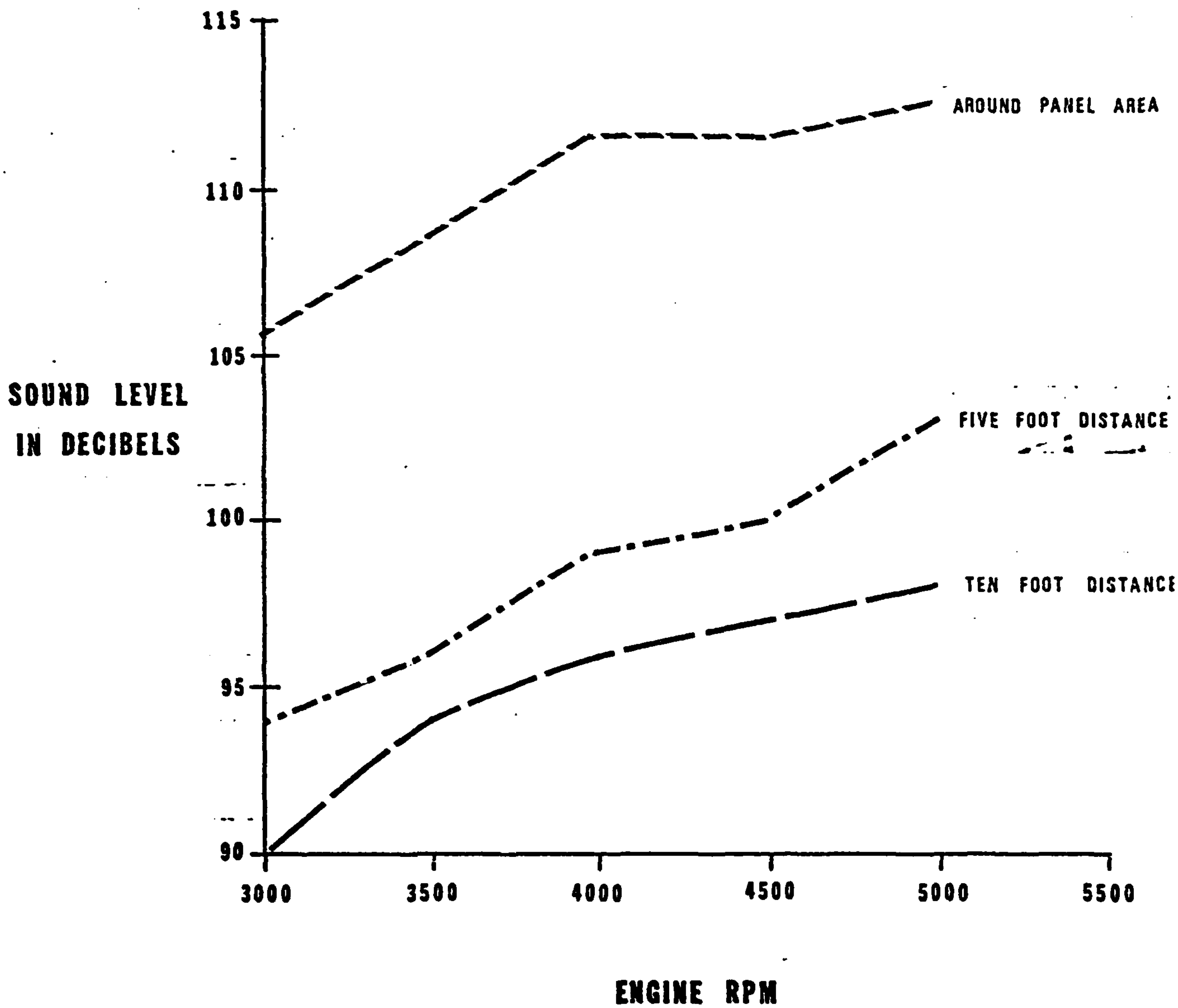

FIGURE 3. SOUND LEVEL EVALUATION

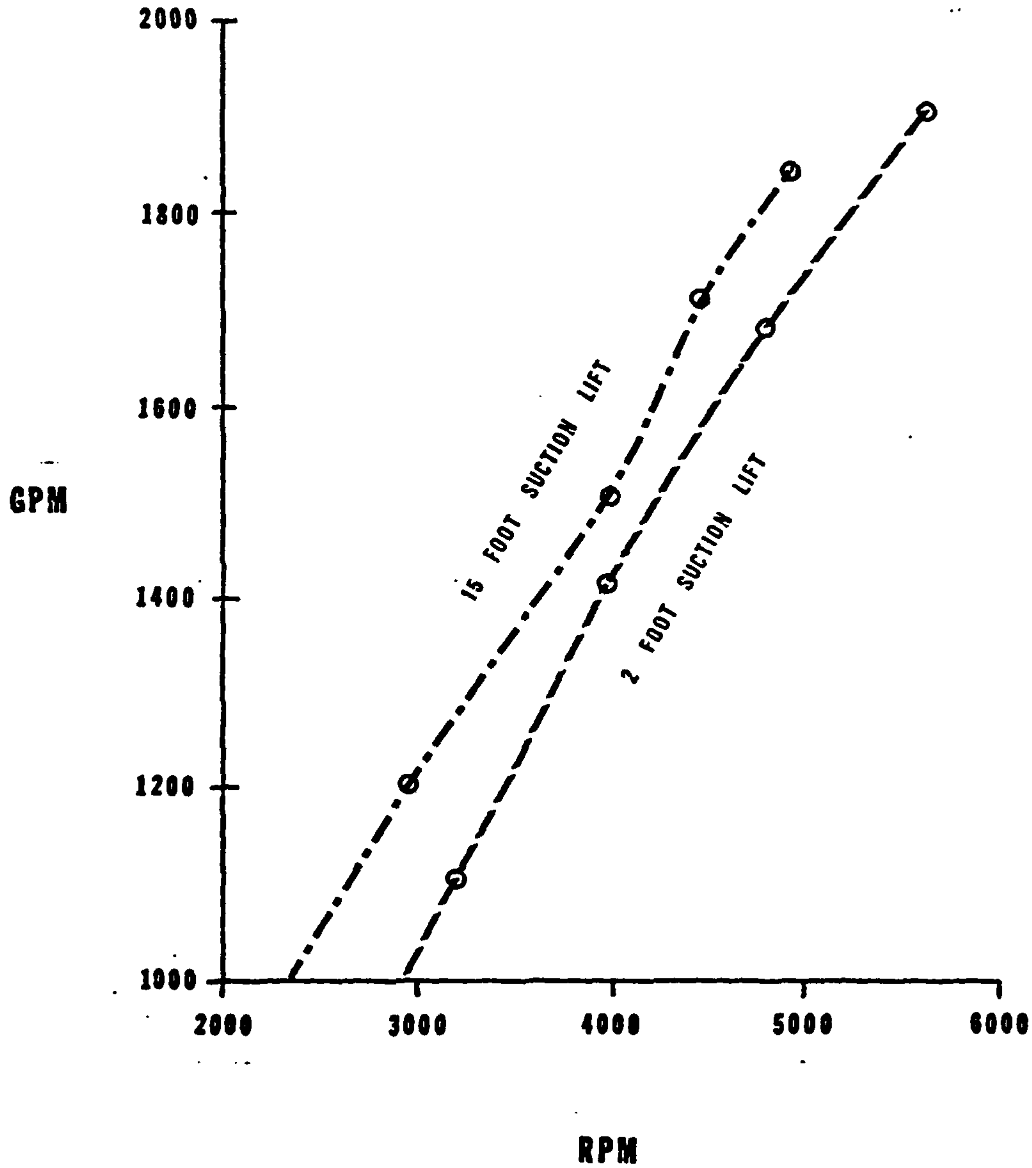

FIGURE 4. PUMP PERFORMANCE

steel wire pennant of at least ten feet and a ball bearing swivel was needed for lifting the module. The suction pipe support bracket had to be removed, and the securing devices for the suction pipe and the suction pipe bracket were not considered adequate for flight operations. On the second day, the module was ready for flight operations. The module was lifted and transported over Mobile Bay, and returned to the pickup point. The helicopter could not place the module back on its trailer. Following the flight the pilot was debriefed. He made the following comments:

a. The pennant was too long (20 feet),
b. In flight the module rotated approximately fifteen times a minute, with a jerking motion
c. The weight of the module and its equipment was of concern because the aircraft had to be lightened by 1 1/2 hours of fuel weight in order to carry the module. This would leave only 30 minutes of fuel for transporting, delivering, and returning. Figures 5 and 6 show the module during the helicopter transport trials.

FIGURE 5. HH HELICOPTER LIFTING MODULE FROM ITS TRAILER

FIGURE 6. IN FLIGHT TRANSPORT OF THE MODULE BY HH-3 HELICOPTER

4.8 32-Foot Ports and Waterway Boat (PWB)

A 32' PWB with a three man crew was provided by MSO Mobile, AL, for this phase of the evaluation. The module was set on the deck of the PWB aft of the deckhouse, and rigged for operation. The monitors had to be secured by means other than bolting through the deck of the PWB. One monitor mounted on the bow on a piece of 3/4 inch plywood, cut to the configuration of the handrail around the bow and secured by U-clamps. Figure 7. The second monitor was aft, as secured to a 4 x 8 foot piece of plywood on which the module was placed. Figure 8.

With the module in operation, the boat was put through a series of maneuvers to check stability and to orientate the crew in how the PWB would react to situations as if it were fighting deck fires or fires onboard ships.

With the module operating at maximum RPM and one monitor position to port, the other to starboard, the nozzle reaction would rotate the boat 360^{0} in 20 seconds. Figure 9. With both monitors trained in the same direction, port or starboard, the boat would develop approximately a ten degree list, and push the boat sideways at 1 - 2 knots.

The stern of the F&STD test ship MAYO LYKES was used to simulate fighting a fire onboard ship. Figure 10. Smoke bombs were ignited in compartments on the stern of the LYKES, and the PWB was manuevered in position to extinguish the simulated fire. The PWB responded very poorly in close quarters as the pressure from the monitors overpowered the engine and rudder control of the boat. The monitor on the stern was used to help the boat's coxswain control the heading of the boat by discharging the monitor into the water around the stern of the boat. Figure 11.

Subsequently both monitors were installed on the bow and then on the stern of the PWB. The monitors on the bow were secured by adding an additional piece of 3/4 inch plywood on the bow for support. This piece was bolted to the first piece. To stiffen up the bow handrails, two come-a-longs were placed one on each side from the handrail to the deck cleat and secured.

Both monitors were also mounted on the stern by securing a 1/4-inch steel plate on top of each corner of the taff rail around the stern. The stern of the MAYO LYKES was utilized again for the simulated fire fighting procedure. Although there was a 100% improvement over control of the PWB, and both monitors could be applied to fire fighting operations, the coxswains view aft was obstructed by the module when maneuvering in the astern mode. Figures 12, 13, 14, 15 and 16.

A measured course was run to determine the maximum speed the PWB could operate at with the suction pipe over the side, and not lose suction to the pump. In 2 - 3 feet waves, wind 15 - 20 knots, vessel headed into the sea at 700 RPM on both engines, the maximum speed obtained without losing suction was 3.5 knots. Figure 15. With the pump suction secured onboard a maximum speed of 19.0 knots was obtained in 3 - 4 sea's, with no problems. Maximum boat speed obtained without the pump onboard was 23.0 knots. A significant problem with the module onboard the 32-PWB is that fact that it must be located on top of the engine hatches. At one time, the starboard engine

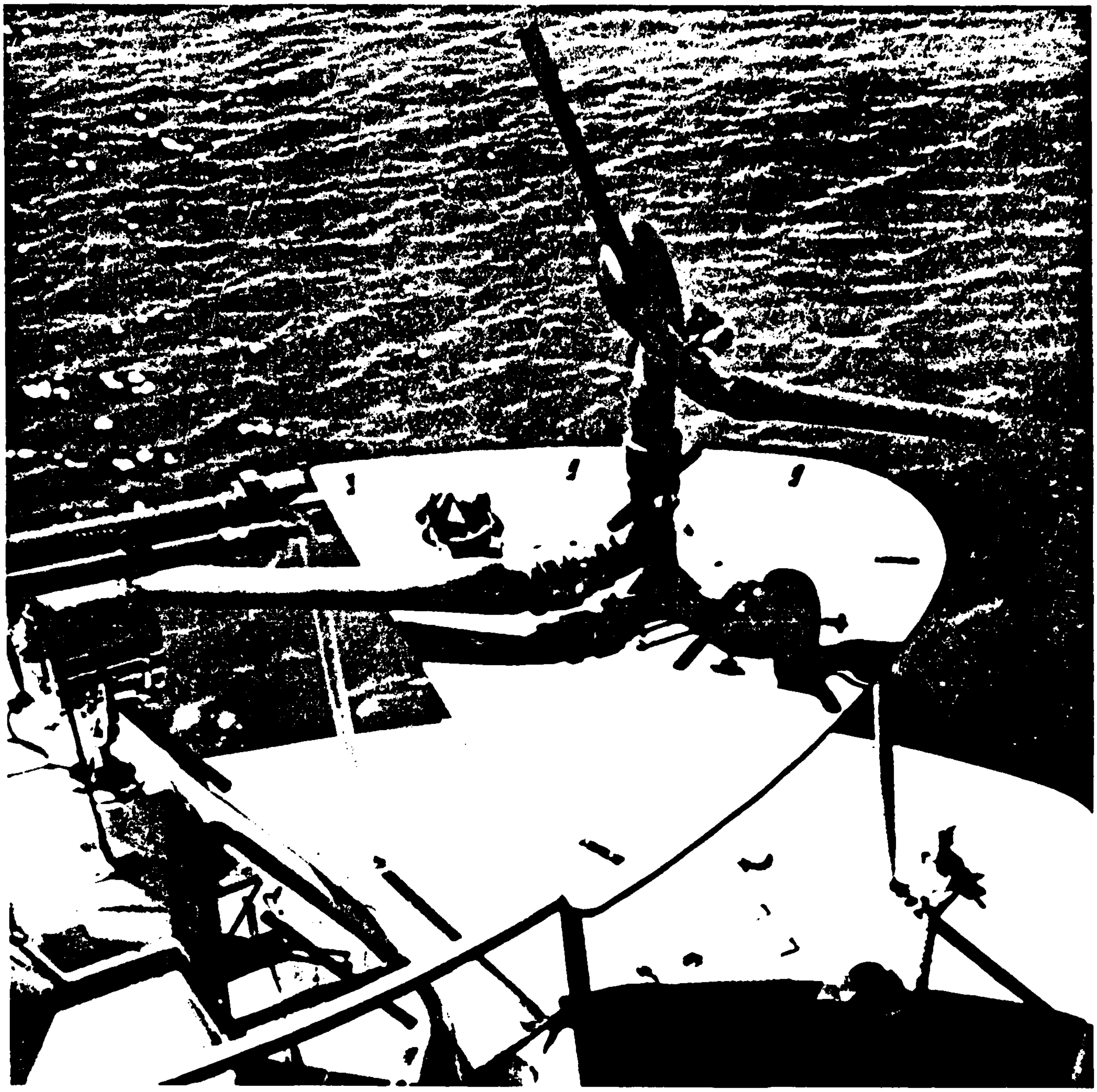

FIGURE 7. SINGLE MONITOR MOUNTED ON THE BOW OF 32' PWB

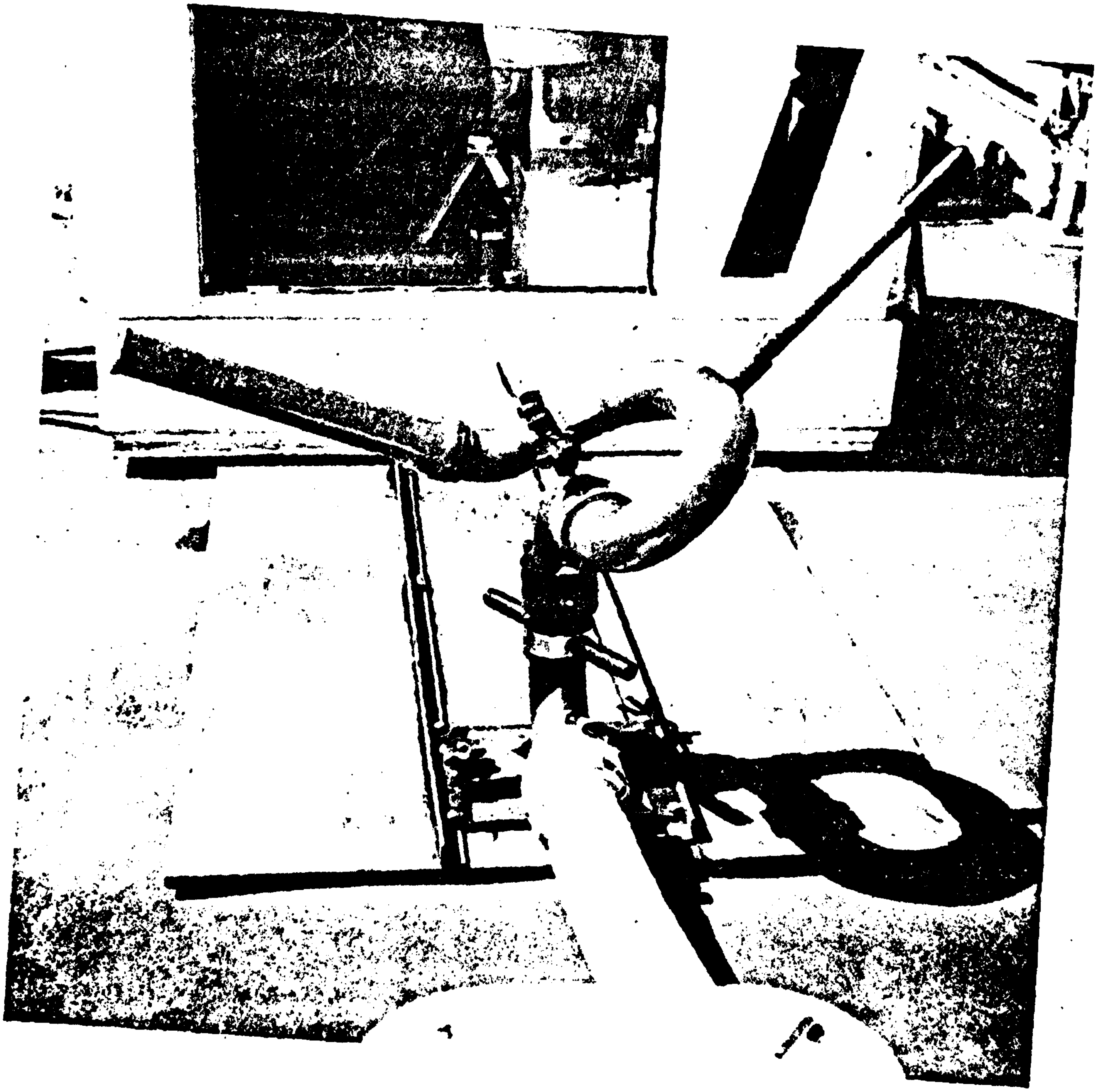

FIGURE 8. SINGLE MONITOR MOUNTED ON THE STERN OF 32' PWB

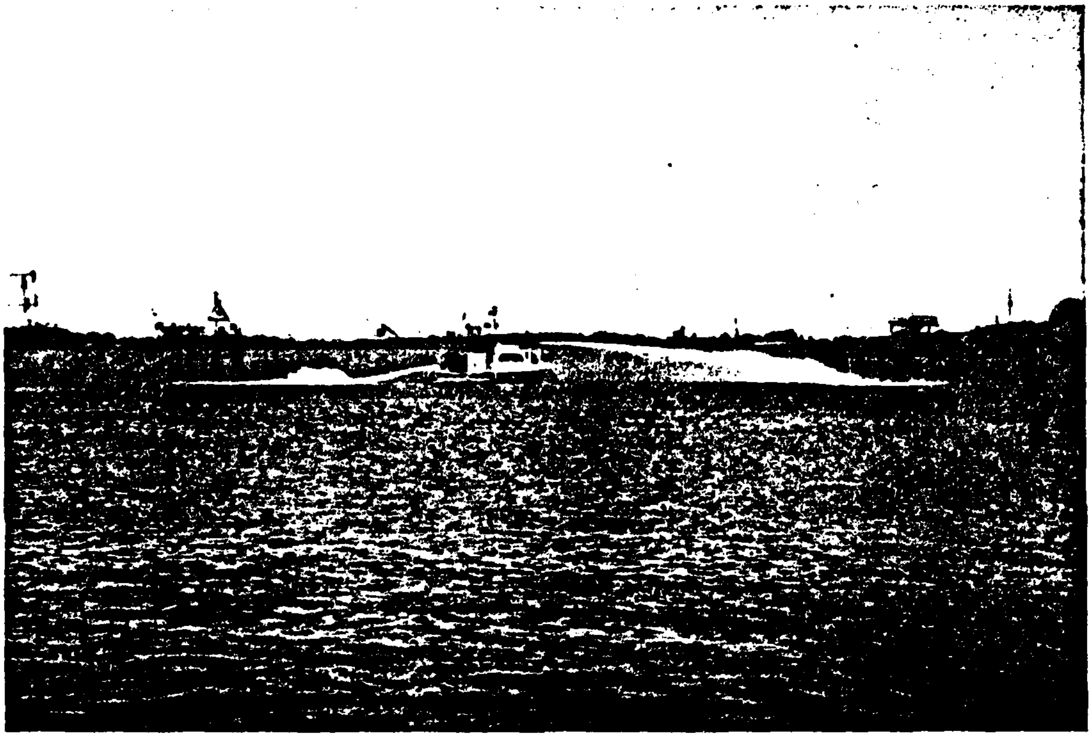

FIGURE 9. TURNING 32' PWB 360° WITH MONITORS

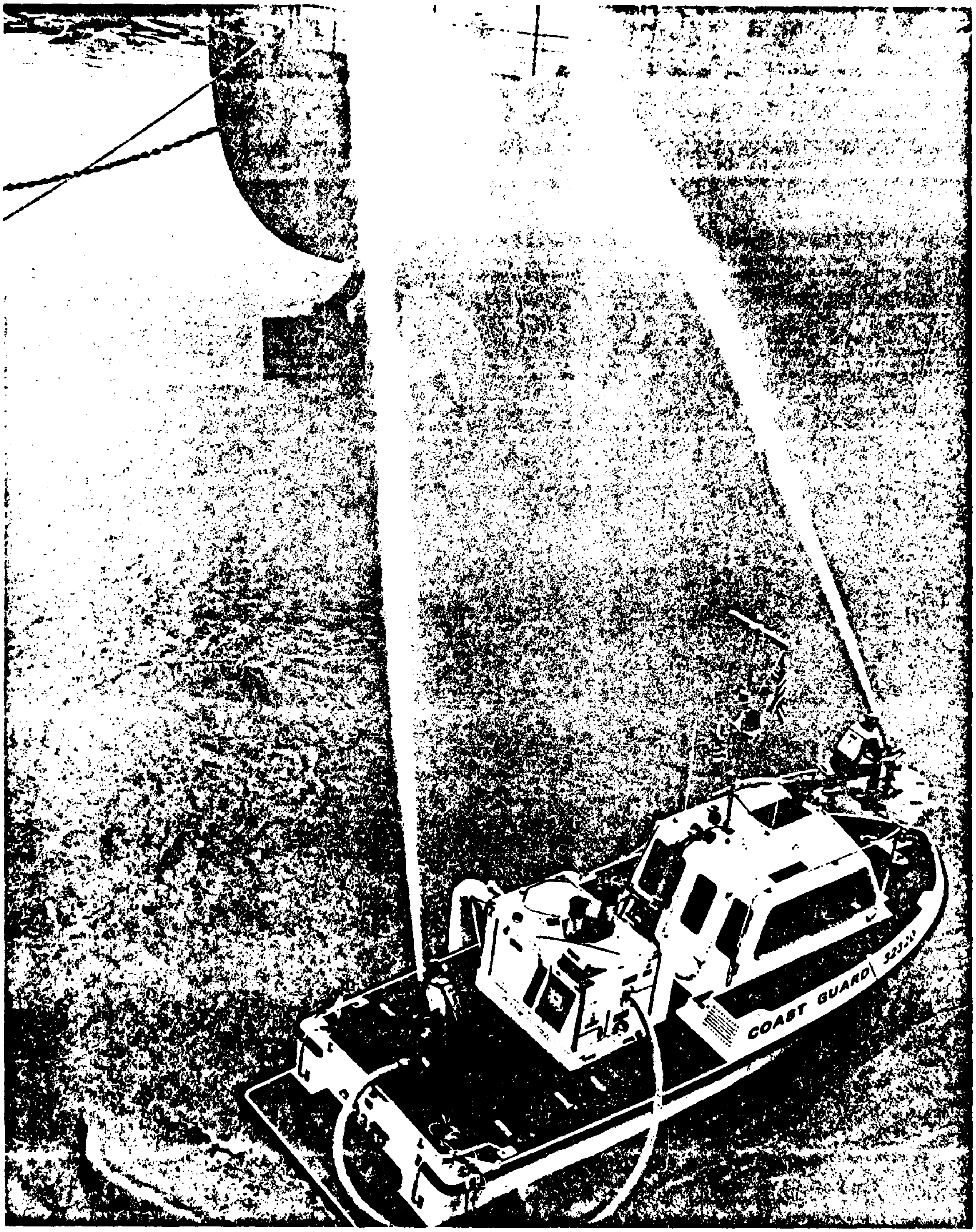

FIGURE 10. FIGHTING SIMULATED FIRE ON BOARD TEST SHIP MAYO LYKES FROM 32' PWB

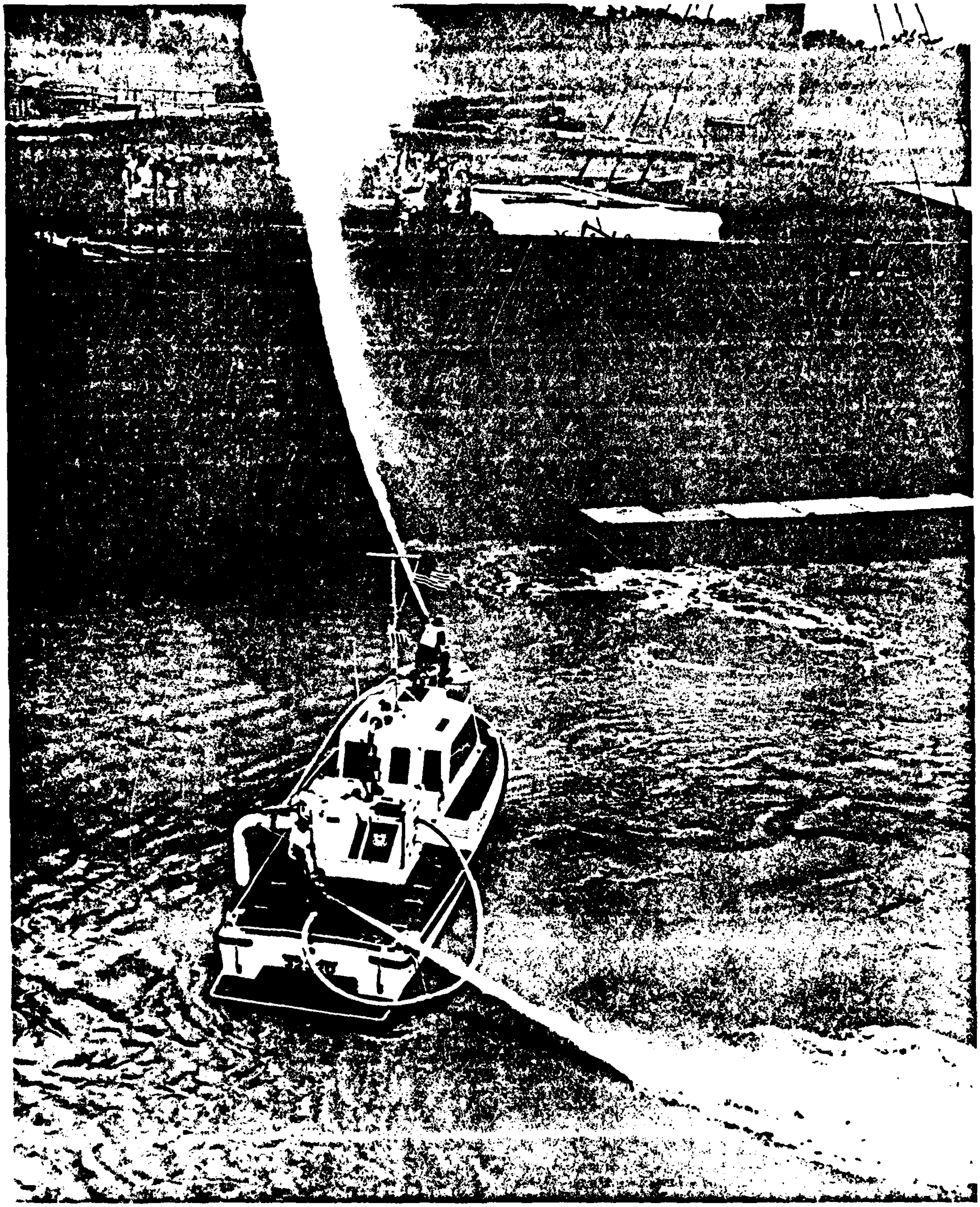

FIGURE 11. FIGHTING SIMULATED DECK FIRE ON BOARD TEST SHIP MAYO LYKES FROM 32' PWB

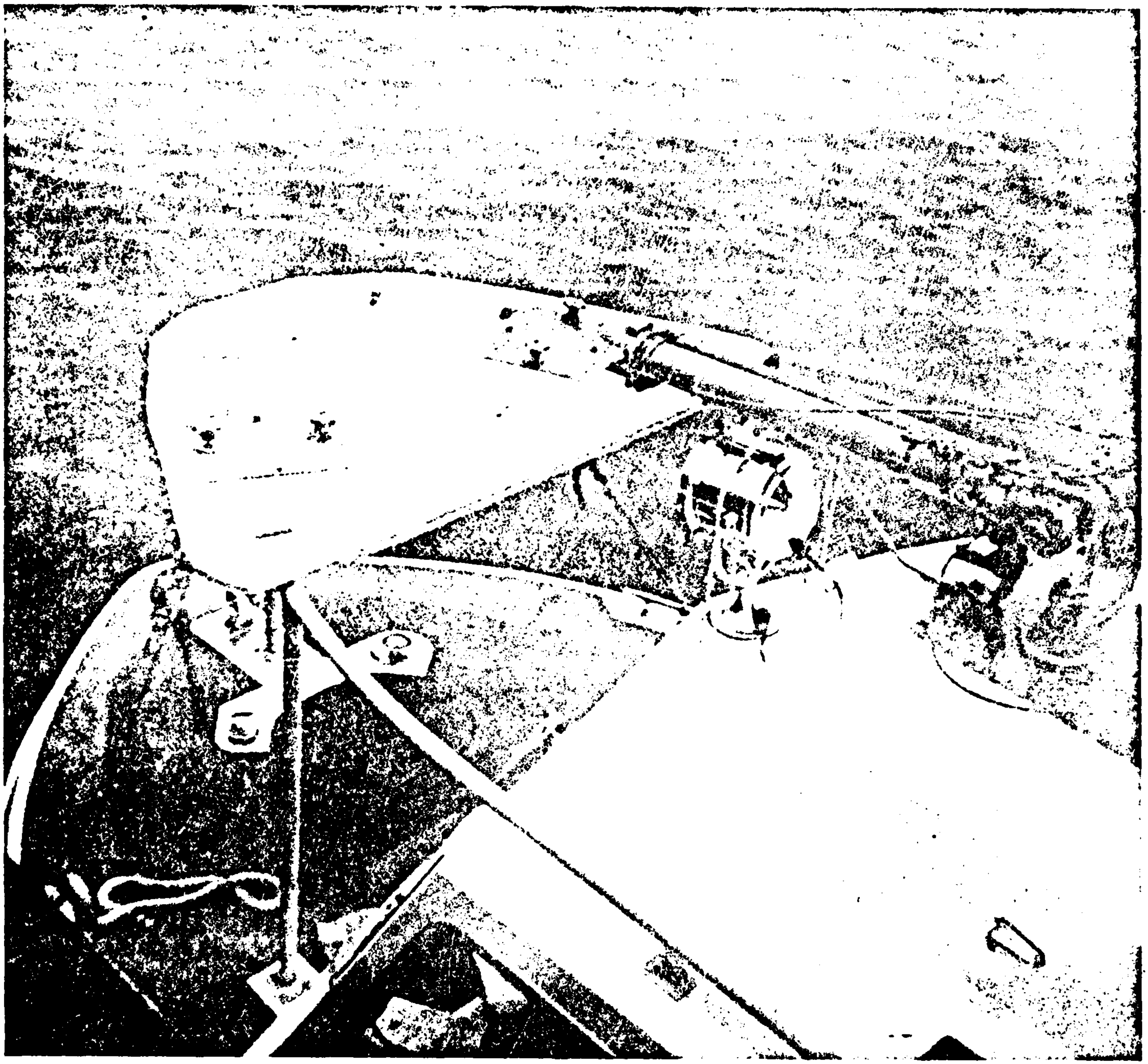

FIGURE 12. ARRANGEMENT DETAILS BOTH MONITORS ON BOW OF 32' PWB

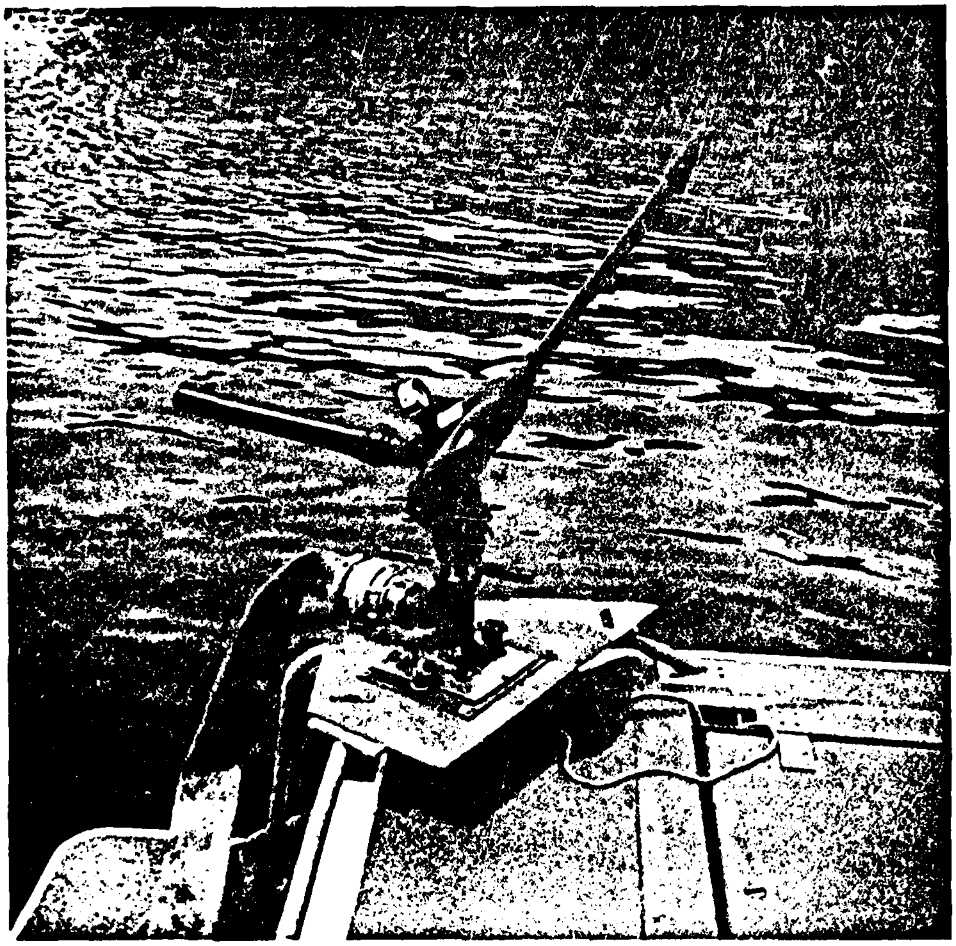

FIGURE 13. ARRANGEMENT FOR BOTH MONITORS ON STERN OF 32' PWB

FIGURE 14. BOTH MONITORS OPERATING FROM BOW OF 32' PWB

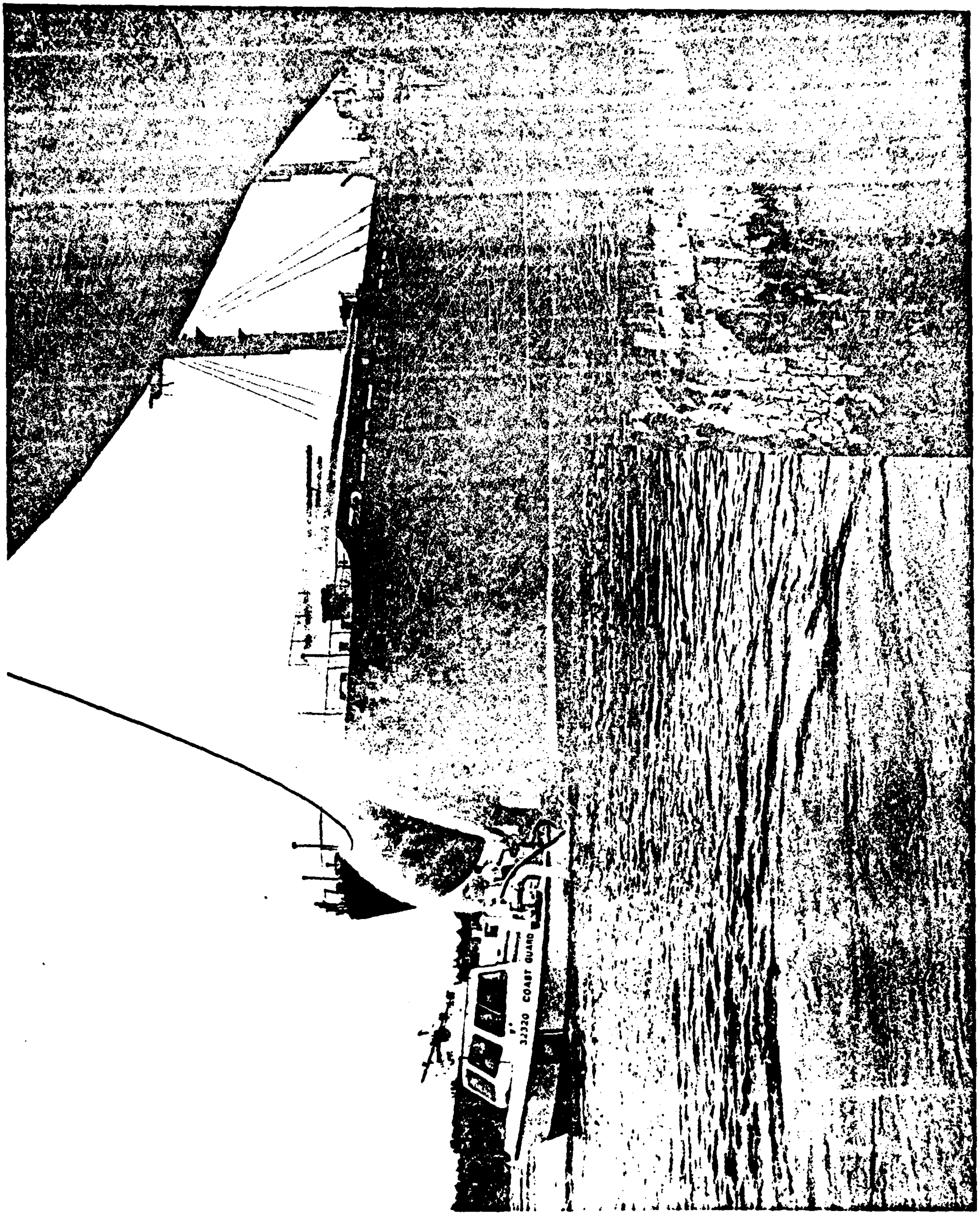

FIGURE 15. BOTH MONITORS OPERATING FROM STERN OF 32' PWB

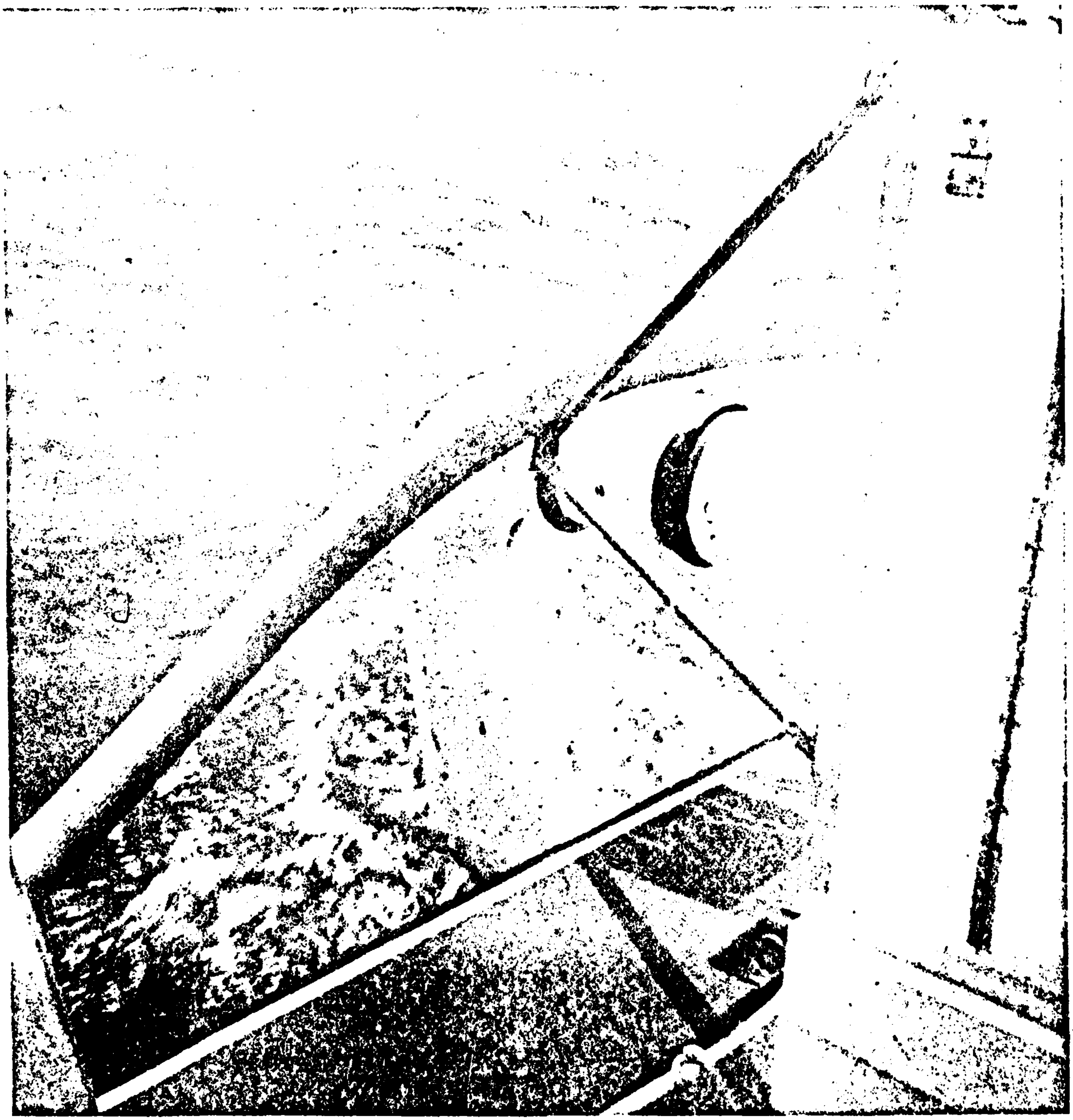

FIGURE 16. SUCTION PIPE EXTENDING INTO THE WATER FROM 32' PWB

overheated. Another time the engine room bilge alarm sounded. Operations had to be secured in both cases to correct these problems since there is no access to the engines, or engine compartment with the module on board.

4.9 82-Foot Patrol Boat Evaluation

In order to evaluate the module's operation from an 82 foot patrol boat (WPB), arrangements were made through CG Group Mobile for the use of USCGC POINT VERDE (CG-82311). The module was placed forward of the deck house and rigged for operation using two, six-foot sections of suction pipe, along with the two-foot strainer section, Figure 17. The monitor on the bow was secured by using the 4 x 8 foot piece of plywood used on the 32-foot PWB. The monitor on the stern was secured by cutting a piece of 3/4 inch of plywood the same size as the lazarette hatch. The plywood was then secured by U-clamps to the hatch securing dogs. Figure 18.

POINT VERDE proceeded to get underway for maneuvers off of Base Mobile. The monitors were trained, one to the starboard and one to the port. At maximum output they turned the vessel 360° in two minutes. No noticeable list was observed when both monitors were trained over the same side.

During this evaluation, a small boat crossed the bow of the POINT VERDE creating a small wake. As the POINT VERDE rolled in the wake, the suction pipe broke at the mating flange and clamping ring causing the module to lose suction. At this point the unit developed other problems and could not be restarted. The operation was secured and the evaluation was discontinued.

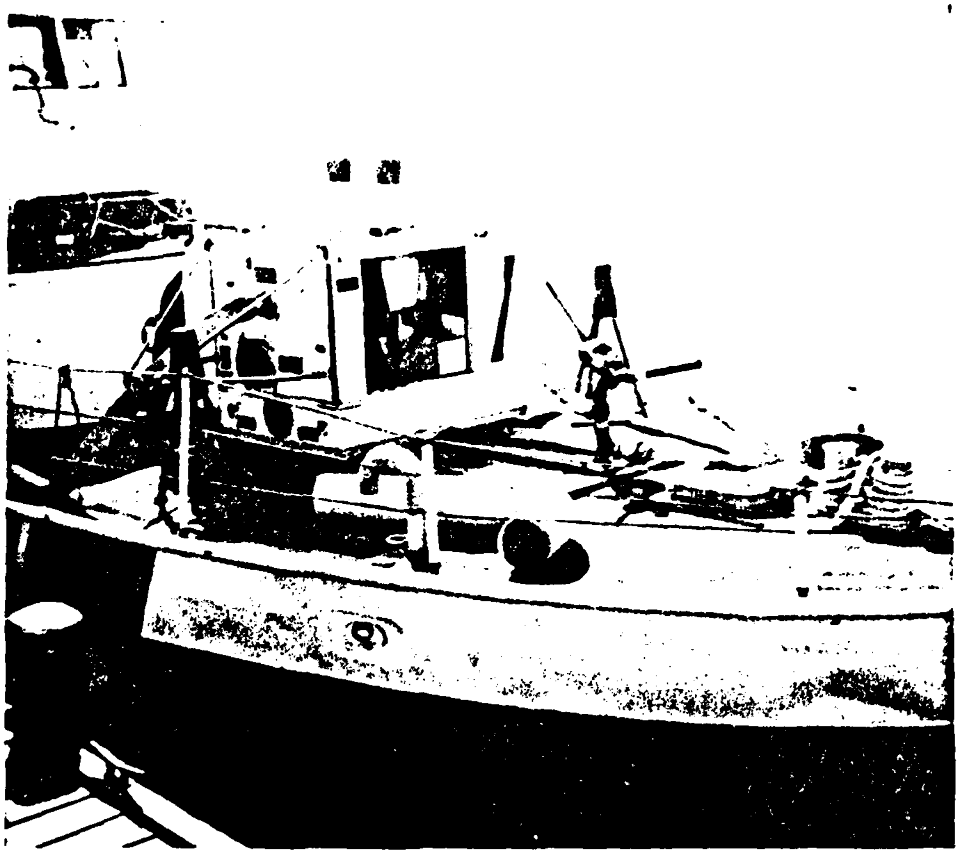

FIGURE 17. MODULE AND MONITOR ARRANGEMENT ON BOW OF 82' WPB

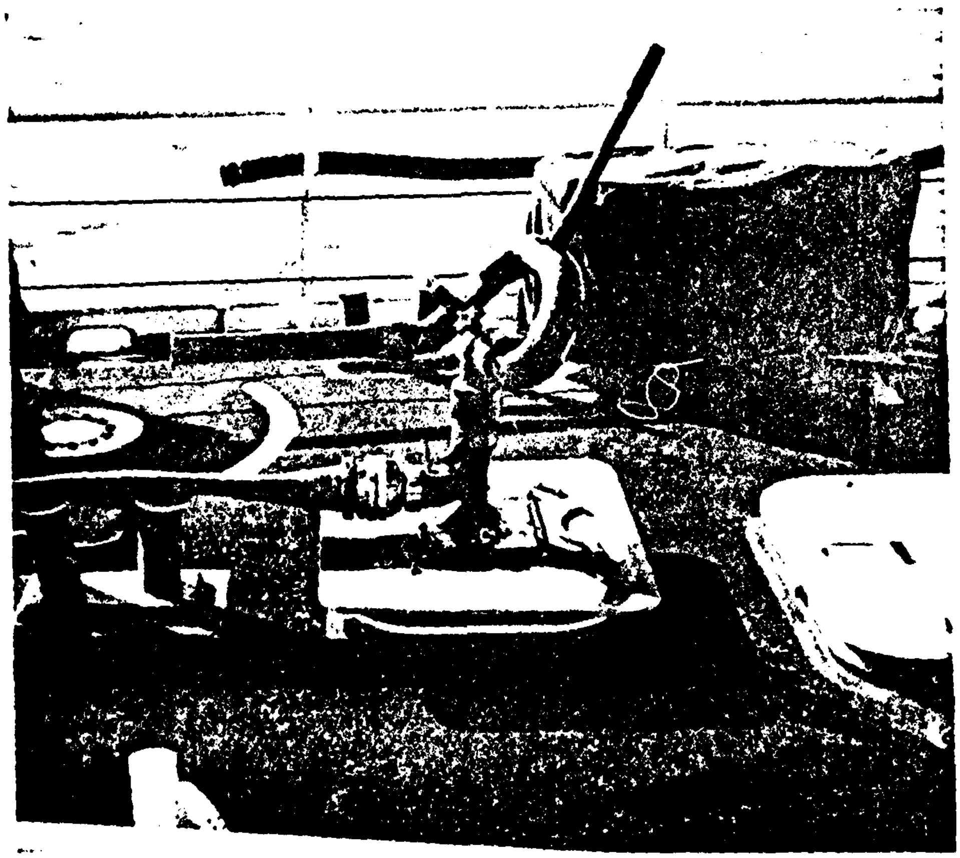

FIGURE 18. MONITOR MOUNTED ON LAZARETTE HATCH OF 82' WPB

5.0 POST EVALUATION TEAR DOWN, INSPECTION AND REPAIR:

Since the pump could not be restarted after the evaluation on the Cutter POINT VERDE, it was decided to do a major tear down and inspection of the pump, which then totaled 122 hours of operation since the testing and evaluation began. The pump was removed, disassembled, and inspected. The inducer housing and bearing assembly was inspected, and found to be in "like new" condition. The main impeller running rings had been spinning in the housing, and worn beyond allowable limits and had to be replaced along with the main impeller. Bearings showed distincive signs of brinelling and were replaced. The quill shaft was damaged on the splines and was replaced. The volute had to be machined to accept the new wear rings. New seals were used when the pump was reassembled.

In summary, the pump was in definite need of overhaul, judging from the condition of the bearings and running rings.

6.0 CONCLUSIONS

Based upon the tests and evaluations, it is concluded that the Lightweight Fire Fighting Module:

a. As presently configured the module enclosure is not suitably weathertight to withstand long term unprotected storage without accumulating water which results in incapacitating critical components.

b. Insufficient attention was paid to the use of non-corrosive fasteners and components.

c. As presently configured, the module cannot be safely air transported.

d. Because of its weight, air transport by HH-3 helicopter is of limited value.

e. The module can be deployed onboard a 32-foot Ports and Waterways Boat, if one is willing to accept that it precludes access to the engine compartment.

f. When used on any boat larger than the 32 PWB, the rigid suction pipe is highly susceptible to damage in the slightest seaway.

g. The Lightweight Fire Fighting module, in its present configuration, is not suitable for service wide use by the Coast Guard without major modification.

7.0 RECOMMENDATIONS

It is recommended that the requirement for the Lightweight Fire Fighting Module be reviewed and, if it still exists, that:

a. Whether this or any other candidate pump is considered, the design be closely reviewed to insure that it meets the requirements for long-term, unattended storage in the weather and air transportability.

b. For deployment on larger vessels, a flexible floating suction hose arrangement be evaluated.